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DEVELOPING FABA BEAN AS A FEED, FORAGE, AND FOOD PULSE FOR THE PRAIRIES

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1. Background

The objective of the project was to initiate a genetic improvement program for development of market-acceptable adapted varieties of faba bean for the domestic forage and feed sector and for the food export sector. The goal of this project was to rapidly develop an adapted germplasm base through plant breeding so that the faba bean crop can eventually play a significant role in the pulse crop sector of the Saskatchewan agricultural economy.

2. Abstract

This project was focussed on developing suitable breeding lines of faba bean for eventual release as varieties to Saskatchewan pulse producers as a crop that is an excellent source of nitrogen fixation, protein and carbohydrate for crop and animal production systems. Substantial progress was made in developing breeding lines of small-seeded white flowered faba beans with improved lodging tolerance, yield and early maturity. These will be used to help develop the faba bean crop as pulse crop for local animal feed and fractionation markets. Large-seeded faba bean breeding lines with improved seed shape and seed coat colour were also developed for eventual release as varieties for marketing into food export markets in the Middle East. Commercial faba bean germplasm from Europe and unadapted germplasm from international collections was screened for potential use in future breeding. The results of the project were promising and were partly responsible for inducing the formation of a prairie wide research and development group focussed on harnessing the economic potential of the faba bean crop.

3. Project Summary

From 2003 to 2006, we screened germplasm collections from various sources around the world to identify potential parents for breeding faba bean with better adaptation and economic potential in Saskatchewan cropping systems. The focus for feed type faba bean was on development of breeding lines with small, round seeds, white flowers (zero tannin), early maturity, reduced lodging, and high yield potential. The focus for food type faba bean was on developing breeding lines with large seeds of suitable shape and seed coat colour combined with high yield, early maturity, and lodging tolerance so that the crop could be marketed at a premium price in the most important markets of the Middle East.

During the project, almost 500 crosses were made starting in 2003. The basic strategy was to introduce traits for improving the productivity and value of faba beans into locally adapted varieties. By the summer of 2006 some lines were available for yield testing in small plot trials at Saskatoon, Outlook (irrigated) and Rosthern. Selections based on yield, seed characters, maturity and lodging tolerance were made each year for advancement to the next generation. By the end of 2006, one white-flowered line was advanced for screening in the 2007 national registration trial. By 2008, many more lines will be available for potential commercialization. The project was successful in rapidly advancing genetic gain n of adapted germplasm for both feed and food types of faba

bean. The Saskatchewan Pulse Growers have now included faba bean as a medium priority pulse crop in a long term research and germplasm development agreement with the Crop Development Centre at the University of Saskatchewan.

During the time frame of this project, the faba bean crop received increasing interest from growers, exporters and secondary processors because of the crop's inherent ability to fix nitrogen and to produce high yield of protein and carbohydrate. Commercial interest developed to the point where grower organizations, crop research organizations, exporters, processing companies and the three prairie agricultural departments formed a Faba Bean Cropportunity team to voluntarily guide crop development of faba bean in the long term.

New faba bean varieties for both the food and feed market streams will derived from breeding lines developed during this project. They will become available for commercial multiplication in 2009.

4. Technical Report

4.1 General Development of Germplasm Base

We collected faba bean germplasm from various sources in Europe, the Middle East and Australia throughout this project. European faba bean breeders from 7 companies provided breeding lines for evaluation. Commercial samples of faba bean were received from industry contacts in Egypt and Australia. The International Centre for Agricultural Research in the Dry Areas (ICARDA) provided international nurseries in each year of the project. The Gatersleben gene bank in Germany provided samples of small-seeded faba beans in the first year of the project for use in the crossing program. The USDA and ICARDA also provided seed samples of specifically requested small-seeded faba bean accessions in2006. Introduced germplasm was crossed with locally bred and adapted faba bean cultivars/breeding lines like CDC Fatima (large-seeded food type) and SSNS-1 (small-seeded).

During the project, some effort was directed toward developing an industry strategy for the faba bean crop, and a more specific effort was applied to encouraging faba bean breeders from Europe to evaluate their material in Canada.

4.2 Materials and Methods

Crossing Program

We completed two cycles of crossing in each year of the project. All crossing was performed in the phytotron facility at the U of S. F1 plants were usually grown in the field in summer, and a more limited number of F1 plants were grown in the phytotron or the greenhouse during the winter cycle.

The crossing program was designed in two streams to suit the project objectives. The first series of crosses was designed to develop extra early, small-seeded, low tannin seeds with round shape. The second series was designed to produce food type faba beans with seed size, shape and seed coat characteristics suitable for the Egyptian market.

During the project 485 crosses were made. Approximately 80% of these involved genetic combinations designed for development of small seeded white-flowered faba beans for use in cropping systems using feed/forage/green manure. In order to rapidly decrease the seed weight of selections, a recurrent selection strategy was used based on evaluation of seed produced from F2 plants and F3 microplots. In the second year, these selections were used as parents in a three-way crossing scheme to rapidly increase the genetic gain in the program for seeds with round shape, small size and zero tannin characteristics. The low vicine/convicine (LVC) trait was introduced into crosses intended for feed use beginning in 2005-6.

Results

A summary of the trial locations and number of lines evaluated per year as part of the project is shown in Table 1.

Table 1. Summary of field trials for faba bean breeding project, 2003 to 2006.

Year	F2 plant populations	F3 plot populations	F4 lines	F5 Lines	F6 Lines	Observation Lines	Coop Lines	Regional Lines
2003	25	7	NA	NA	NA	90-3-1	4-3-1	NA
2004	306	25	12-2-2	NA	NA	NA	7-3-1	NA
2005	79	80	1458-1-2	12-2-2	NA	69-3-1	NA	NA
2006	82	37	1108-1-2	435-2-3	3-2-4	94-3-1	6-3-4	13-3-2

For F4 and later generations, first number refers to number of lines, second is the number of replications, third is the number of locations.
NA Not applicable

Beginning in 2003, segregating populations derived from hybridization were evaluated in the field as F_2 plants every year. A small number of white-flowered F2-derived F3 rows were evaluated in field in 2003. Starting in 2004, F_3 microplots were evaluated every year, and starting in 2005, standard yield nurseries using in 3-row and 4-row plots at the F_4 to F_6 generations. Field plot techniques were modified as required, and the number of locations was expanded to accommodate the biological progression in the breeding program. Rosthern (dryland) and Outlook (irrigated) were included as screening sites ite beginning in 2005. During the project, the majority of the plot trials were grown at the SPG farm near Saskatoon and at the Preston Avenue plot area, especially during the first 2 years.

Segregating populations and breeding lines were evaluated for flower colour, maturity, plant height, lodging, seed weight, seed shape, and seed coat characters such as presence or absence of seed coat tannin and colour retention for normal tannin food types.

In 2004 all yield trials were direct harvested with a Wintersteiger small plot combine. In 2005, the yield trials were divided into two groups. The first group of trials was desiccated with Reglone prior to direct combining. The second group of plots was swathed with a small plot canola swather at the black pod stage and then threshed later using a small plot combine equipped with a Sund pickup. In 2006, all plots were harvested using the swathing method.

The summer of 2003 had heat and drought as the main stress factors for selection in the faba bean field nursery. Seed of ten of the earliest flowering and highest yielding F_2-derived F_3 short rows was sent to Arizona in the fall of 2003 for seed multiplication. All lines were low tannin with smaller seed than that of other white-flowered varieties available in Canada. Our intent was to assess genetic progress in selection for small-seed low tanning (white-flowering) types from the first round of single crosses. Six of the 10 lines produced sufficient seed for entry into a 2-location preliminary yield trial in summer of 2004 as F_2-derived F_4 lines. All 6 lines flowered at least 7 days earlier than the checks. Yield potential was close to the checks for some of the lines, and seed weight was close to mid-parent values. Our conclusion from this limited amount of data was that good potential exists for developing high-yielding early maturing lines of low tannin faba bean varieties with small seeds. In 2005 the top 4 lines were evaluated in a two location trial and in 2006 the top line was included in an observational trial to compare performance to checks and to current breeding lines from Europe. Based on the performance of this "forerunner" line developed from a cross between a European line and a line from Bangladesh, we can predict that there is great potential to improve yield for white-flowered faba beans while improving lodging resistance, early maturity and plant height (Table 2).

Table 2. Faba bean observational trial No. 1 results 2007

		[2]	[2]		[2]	[1]	[1]	[2]	[2]
		Yield		Flower	Days to	Days to	Lodging	Height	Seed Wt
Line	Origin	kg/ha	% Fatima	colour	flower	Maturity	1-5	cm	mg
CDC Blitz	Saskatoon	2942	89	normal	52	105	5.0	55	357
CDC Fatima	Saskatoon	3324	100	normal	48	99	4.5	52	413
83A1283	France	3337	100	white	52	106	5.0	56	485
80B1180	France	3328	100	white	52	105	5.0	55	409
77A1056	France	3128	94	white	52	105	5.0	55	465
Diana	France	3264	98	normal	51	100	3.5	52	328
SR604.3	France	2510	76	white	53	106	2.0	54	445
FB6-AZ-10	Saskatoon	3334	100	white	48	103	2.0	53	400
Felecie	Austria	2389	72	normal	52	105	2.5	54	290

[x] Number of sites

The Faba Bean Co-operative trial was rejuvenated in 2004 and grown at 5 locations across the prairies. In 2005, the trial was not grown because of the limited number of entries. In 2006, renewed interest in the faba bean crop resulted in entry of many new lines in the white-flowered category. The summary of results in Table 3 shows that many of the newer lines are high yielding and show improved lodging tolerance.

Table 3. Summary of agronomic performance data for the 2006 Faba Bean Co-operative Trial in western Canada

Years in trial	Entry	[5] Yield kg/ha	[5] Yield % Fatima	Flower colour	[5] Days to flower	[5] Height cm	[2] Lodging 1-5	[3] Days to mature	[5] Seed weight mg	[5] Seed weight % Fatima
1	Valeria	1951	74	W	47	99	3.7	95	402	92
1	Disco	3012	115	W	47	95	3.5	95	549	125
1	NPZ5-7530	2992	114	W	46	91	3.8	95	455	104
1	Gloria	2448	93	W	46	88	3.5	93	378	86
1	NPZ4-7540	2571	98	W	46	87	2.0	95	414	94
1	NPZ4-7460	2616	100	W	45	87	1.5	96	409	93
1	Dixie	2264	86	W	44	80	3.8	93	441	101
1	Louxor	2379	91	W	46	80	1.7	94	385	88
1	CEB04928	2739	105	W	47	92	2.8	96	536	122
2	NPZ3-7080	2717	104	C	44	88	1.5	97	525	120
1	IN 05930	2641	101	C	45	95	1.3	97	521	119
1	Syn	1933	74	C	49	87	1.8	98	300	68
C	**CDC Blitz**	2334	89	C	48	93	4.2	95	354	81
C	**CDC Fatima**	2621	100	C	45	98	4.3	94	439	100

Bold indicates check

W - white
C- coloured

1 - upright
5 - flat

[X] Number of sites

Lodging: 1 - best; 5 – worst

Other Factors Influencing Research Direction and Progress

- *Faba Cropportunity Team*

Beginning in 2006, the Saskatchewan Pulse Growers developed the concept of forming a prairie wide Faba Bean Cropportunity team to help promote streamlined development of the crop on a long term basis. Interested individuals were invited from the three prairie pulse grower organizations (Mantioba Pulse Growers Association, Alberta Pulse Growers Commission and SPG) and from various federal, provincial and university based research groups and industry representatives from the fractionation industry.

General agreement was reached that faba bean crop development was a worthwhile long term investment. The group met 3 times in 2006 to develop a strategy for long term crop development strategy encompassing the production and processing of faba bean in food, feed and industrial applications. Detailed documentation is available from the Saskatchewan Pulse Growers.

Highlights of the strategy include development of faba fractions for use in protein isolates for fish meal, development of faba bean as a nitrogen source for prairie crop rotations, development of a limited food export market with high quality seed type, development of a local feed industry based on zero-tannin (white-flowered) and low vicine/convicine faba bean germplasm.

- *Linkages with Other Research and Development Groups*

As a result of developing links with the European pulse research community, Dr. Vandenberg was invited to participate in the EUFABA meeting in Dijon in December 2005 and the International Faba Bean Breeding and Agronomy Workshop held in Cordoba in 2006. Contacts made at these meetings were valuable for developing linkages with private breeding companies and researchers from many parts of the world, especially Europe.

The development of the Canadian Faba Bean Cropportunity team has instilled confidence in the international faba bean breeding community that Canada is serious about developing a long term strategy for the crop and that the objectives for germplasm development in Canada are unique.

- *Faba Bean Breeding Program Upgrade*

As part of the long term pulse breeding agreement between CDC and SPG, faba bean was upgraded to medium priority status in 2006. This means that the core faba bean breeding activity will continue as part of the regular effort at the CDC at the end of this project. The future breeding program will work closely with the Faba Bean Cropportunity team members to maintain focus on market-based objectives in genetic improvement. In 2007, breeding lines from this project will be entered into multilocation trials at the adanced (1st year) and elite (2nd year) level. One line will be entered into the Coop trial for potential registration in 2009.

Main Conclusions and Impacts

The main conclusions of this project based on development of new breeding populations and evaluation of breeding lines up to the F6 generation include the following.

- Populations derived from crosses between local varieties like SSNS-1 and small-seeded faba bean lines collected from Bangladesh show a significant reduction in

time to flowering and maturity. It should be possible to develop earlier maturing lines for Saskatchewan production with little difficulty.

- The same crosses segregate in continuous distribution for seed size, making it feasible to quickly develop small-seeded white-flowered lines with extra early maturity. We expect to release initial varieties of this type by 2009 for wide distribution to potential growers in Saskatchewan.
- The maturity range, yield and quality profile of breeding lines of food type faba beans developed in this project is acceptable. Yield potential of the most advanced breeding material was very high.
- A large range of variability is available within food types for seed colour retention and it should be feasible to develop varieties with excellent market acceptability by 2009.
- Mexico or New Zealand could be considered as potential winter multiplication sites for faba bean.
- Faba bean breeding has now been upgraded to medium priority status by the Saskatchewan Pulse Growers. Crossing will continue, as well as field and growth room evaluation of new germplasm accessed from northern Europe.
- Winter multiplication of faba bean is feasible based on preliminary assessments in Sinaloa, Mexico in the winter of 2005-2006 and Yuma, Arizona in 2006-2007, feasibility of using this as a timely winter nursery site when we wish to make the first major seed multiplications of lines derived from this breeding project.
- Canada is now being recognized as a potential place to develop new germplasm for specific markets by European faba bean breeders.
- The faba bean crop has developed some respectability in the research community and among producers as a crop that has future potential in prairie cropping systems.
- The CDC breeding program developed systems for rapid screening of seeds that exhibit the zero tannin (slow darkening) phenotype by use of UVC lights and colour sorters.

Recommendations for Faba Bean Crop Development

The following recommendations are made based on the results and the experience gained during the course of this research project.

- Future genetic improvement will be greatly enhanced by providing incentives for faba bean breeders with a similar strategy as that developed by SPG for field pea (Pea Genetic Improvement Program)
- Further improvements in faba bean are possible, especially for traits of economic importance in future such as low vicine/convicine, low phytate, high protein to increase feed value, low protein to improve carbohydrate value, small round seed to improve extaction and cost of production profile. Research investment in these areas would be worthwhile.
- Lygus bug remains a problem for faba bean, particularly for product intended to enter the whole seed export market. It may be worthwhile to conduct research on a strategy to control this pest.

- SPG could consider tendering out the development of food type export varieties for a seven year period to ensure more orderly market development of this potential export product. This could be considered as early as the 2008 cropping season.
- Small round-seeded, white-flowered faba bean has excellent potential to serve as a local source of feed for livestock, for on-farm soil nitrogen production, and as a source for protein and starch extraction. These opportunities can be best realized by participating in a long term coordinated approach as represented by the Faba Bean Cropportunity Team.
- Potential may exist in the Indian sub-continent for use of dehulled split faba bean as high protein flour or as a new dhal. This would require overseas market development. A pilot project could be organized through Tamil Nadu Agricultural University which has developed a research relationship with the College of Agriculture at the U of S.
- Successful crop development will require development of a realistic crop insurance program for faba bean.

Project Communications

This project was discussed in various industry research strategy meetings beginning in 2004. In 2006 these discussions were formalized by the formation of the prairie wide Faba Bean Cropportunity team. The group met 3 times in 2006 with the objective of developing a long term development strategy for the crop.

The breeding project was also described at summer field days at SCIDC in Outlook, July 8, 2004.

This project was featured at the SPG summer field day at Saskatoon, July 2005.

The breeding project progress was reported at a, AAFRD sponsored conference on opportunities for lupin and faba bean held in Nisku, Alberta in November 2005.

Faba bean research and development was featured in an invited article in Pulse Point in 2005.

The project was summarized at a grower information day held at Canora in March 2006.

The breeding project was featured at the SPG summer field day at Melfort in July 2006.

Faba bean and its associated economic opportunities in Saskatchewan cropping systems were the focus of an invited presentation at Pulse Days 2007.